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RESEARCH ARTICLE

Occurence of the alien species *Caprella scaura* (Amphipoda: Caprellidae) in three Tyrrhenian lagoons

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Abstract

1 - Alien species represent a recognized worldwide threat to the integrity of the native communities, to the economy and even to human health; hence the understanding of invasive processes and their impact on the invaded ecosystems are essential to environmental conservation and management.

2 - In this paper we have reported, for some Italian lagoons, the first record of the alien species *Caprella scaura* Templeton, 1836, an amphipod species native to the Indian Ocean and now recorded worldwide.

3 - Specimens of *C. scaura* were collected in three Tyrrhenian lagoons (Santa Gilla, Caprolace and Fogliano), sorted into 5 categories (juveniles, males, immature females, mature females, breeding females) counted and measured for their total length.

4 - In Caprolace and Fogliano lagoons very few specimens were collected, while in the Santa Gilla samples a considerable number of individuals were found, particularly juveniles and immature females.

5 - Total length values of our specimens were lower than those reported from others Mediterranean areas.

6 - The introduction of this species in Caprolace and Fogliano lagoons is clearly a recent event while in Santa Gilla lagoon it is undefined.

Keywords: *Caprella scaura,* Brackish water environment, Tyrrhenian lagoons, length-frequency, alien species.

Introduction

Biological invasions represent a recognized worldwide threat to the integrity of the native communities, to economy and even to human health (Streftaris and Zenetos, 2006). Invading organisms, indeed, may affect systems by altering ecosystem processes, disrupting trophic dynamics, disturbing and degrading habitats, or directly competing, parasitizing or preying upon native species (Ruiz *et al.*, 1999).

Species could be considered invasive when interfering with the establishment and survival of native species with concurrent ecological or socio-economical costs (Elliott, 2003). Nevertheless, not all the allochthonous species are able to become invasive in a new habitat; however, when they do, they extend the geographical range of distribution and rapidly increase their populations (Occhipinti-Ambrogi *et al.*, 2011).

Among the alien species collected in the Mediterranean area, the amphipods of the family Caprellidae seem to have a particularly strong invasive power. Indeed, the number of caprellid species reported from the Mediterranean has increased from 23 known species in 1993 to 41 reported in 2010, although only 21 can be considered Mediterranean endemics (9 of which have a distribution area restricted to the Strait of Gibraltar) (Sturaro and Guerra-Garcia, 2012). 17 species belong to Italian fauna, 14 being of the genus *Caprella*, 2 of the genus *Parvipalpus* and one of *Pseudolirius* (Ruffo, 2010).

Among these species, *Caprella scaura* Templeton, 1836, native to the western Indian Ocean, is one of the 20 non-indigenous species recorded for the Mediterranean basin in recent years (Martinez and Adarraga, 2008). It was collected in the Mediterranean area, for the first time, in the Venice lagoon (Sconfietti and Danesi, 1996; Mizzan, 1999) and later reported in other Italian sites: Grado-Marano lagoon (Sconfietti *et al.*, 2005), Sicily (Krapp *et al.*, 2006), Tyrrhenian coasts off Livorno (Galil, 2008), Mar Piccolo of Taranto (Elefheriou *et al.*, 2011) and in other Mediterranean areas such as Gerona (Martinez and Adarraga, 2008) and Greece (Krapp *et al.*, 2006).

This work aims to report the occurrence of the alien species *C. scaura* in three Tyrrhenian lagoons along the Sardinia (Santa Gilla) and the Latium (Fogliano and Caprolace) coasts and to give some information about population structure, being essential for understanding the invasive process and impact on the invaded ecosystems (Krylov *et al.*, 1999; Prato *et al.*, 2012).

Material and Methods

Description and remarks

Caprella scaura is easily distinguished from the other species of the genus by the acute spine on the head in both sexes. This species shows a marked sexual dimorphism: the pereonites 1 and 2, as well as the basis and the propodus of gnathopod 2 are elongated in males. The palm of gnathopod 2 has 2 strong proximal and distal teeth respectively, although the propodus of gnathopod 1 has 2 proximal spines. The gills are elongate and elliptical. In females, knobs on some pereonites are present. The basis of gnathopod 2 is shorter than that of the pereonite 2 while the propodus of the gnathopod 2 is not elongated, its palm with proximal spines and small distal tooth. The propodus of the gnathopod 1 is similar to that of the male. The gills are elliptical but shorter than in males. In both sexes antenna 1 is nearly twice the length of antenna 2. Finally, the juveniles differ from adults. The cephalosoma is roundish and the occipital spine is absent; the antenna 1 and 2 are similar in length; the gnathopod 1 is as long as the gnathopod 2 and gills are roundish and shorter than in adults (Martinez and Adarraga, 2008; Krapp *et al.*, 2006).

Study area

Santa Gilla lagoon covers an area of about 1300 ha and is located along the Southern coast of Sardinia between the historic port and the industrial one, each serving a different type of traffic (Fig. 1A). In the south the lagoon opens onto the sea through a channel, while in the north it receives two freshwater inflows from the Flumini Mannu and Cixerri. The average depth is 100 cm (maximum depth 200 cm). The sediment is mainly sandy-silt (Degetto *et al.*, 1997; Frontalini *et al.*, 2009).

The Fogliano and Caprolace lagoons belong to the wetland of the Latium region in the

Figure 1. Santa Gilla (A), Fogliano and Caprolace (B) lagoons with the sampling stations.

remains of the Pontine marshes along the middle Tyrrhenian coast (Fig. 1B). The Fogliano lagoon covers 404 ha and has an average depth of 100 cm (maximum depth 200 cm). It has three mouths, one opening onto the sea and two connected with freshwater canals, these latter being kept closed at present owing the canals' eutrophic load. The Caprolace lagoon has an area of 216 ha and an average depth of 130 cm (maximum depth 290 cm). It has two mouths opening onto the sea, one at the North side and the other in the central area. The bottom sediment of both the lagoons is of silt and clay with many scattered organogenous deposits, such as the valves of the halolimnobic bivalve *Cerastoderma glaucum* and vegetation debris (Gravina *et al*., 1989).

Field and laboratory methods

In the Santa Gilla lagoon the specimens were collected seasonally from samples taken in order to characterize the macrozoobenthic community of this lagoon (July 2010, October 2010, January 2011 and March 2011) in 3 stations along a salinity gradient. Station 1 (S1) is the nearest to the sea, station 3 (S3) is the nearest to the freshwater sources while station 2 (S2) is intermediate. In the lagoons of Fogliano and Caprolace samples were taken seasonally from February 2011 to January 2012, in 8 and 6 sampling sites respectively. In the Fogliano lagoon the central area (stations F5, F6, F7) is directly under the influence of the sea, while the stations F1, F3, F4 show a low degree of confinement which, by contrast, is pronounced in the stations F2 and F8. In Caprolace lagoon the marine influence is widely appreciable in the stations C2, C3, C6, while the other stations (C1, C4, C5) are slightly confined (Gravina, 1986; Nicoletti *et al*., 2006). No remarkable freshwater inputs flow into either of the two lagoons.

For Santa Gilla lagoon depth (cm), temperature (°C), salinity (psu), conductivity (ms/cm), dissolved O_2 (mg/l; %sat) and pH of the water were measured, while for Latium lagoons depth (cm), temperature (°C) and salinity (psu) with a multiparametric probe (Hanna HI 9828) were recorded.

The samples were taken with a Van Veen grab, for a total surface of 0.18 m^2 in Santa Gilla lagoon and 0.10 m^2 in Fogliano e Caprolace lagoons.

Each sample was washed through a 1 mm mesh screen and narcotized with 7.5% magnesium sulfate. The material retained was fixed in 4% buffered formaldehyde and preserved in ethylic alcohol.

Specimens of the species *C. scaura* were identified at 7-40 x magnification by means of a stereomicroscope and, for the juvenile specimens, at 20-200 x magnification by using an optic microscope (Labrolux 12). Identification was based on the morphological description provided by Templeton (1836), Guerra-Garcia (2003) and Krapp *et al.* (2006). All the specimens in each station were counted and a multiple regression analysis was performed on abundance data and the main environmental parameters (Statgraphics Plus, v. 5.1).

For each specimen, the total length (LT), from the anterior margin of the head to the posterior margin of the telson, was measured and five developmental categories were identified: juveniles, immature females, mature females, breeding females and males. Females were separated on the basis of presence/absence of the oostegites and the presence of eggs in the marsupium. Mature females were considered as being those with fully formed oostegites, as they appear only at the moult which precedes mating and egg-laying (maturation moult) (Lincoln, 1979). The sex ratio was calculated as the relationship between the female specimens and the total population (FF / (FF + MM)).

For both sexes, the length-frequency distributions of the five categories were analyzed for the stations where the number of the specimens was sufficient; comparison among distributions for each station and season were performed using the Kolmogorov-Smirnov test.

Fecundity was estimated from the total number of external eggs forming the whole clutch. The eggs carried on the brood pouch were removed with a spatula and counted. Their minimum and maximum diameters were measured using a graduated ocular. The partial fecundity index (mean brood size/ mean female size) and the age of reaching maturity index (minimal/mean breeding female size) were also calculated.

Results

The variation in abiotic parameters of the water, for the investigated stations, throughout the sampling period is shown in Table 1 for Santa Gilla lagoon, and in Table 2 for Fogliano and Caprolace lagoons.

In Santa Gilla lagoon the water temperature showed the lowest value in January (11.4°C) and the highest value in July (28.7 °C); in Fogliano and Caprolace lagoons, it varied from 9 in February to 30 °C in July. In Santa Gilla at stations S1 and S2 salinity

Tabella 1 - Values of the water variables at different stations and months in Santa Gilla lagoon.

Station	Date	Depht (cm)	T (°C)	Salinity (psu)	Cond (mS/cm)	pH	OD (mg/l)	OD (%sat)
S1JUL	08/07/2010	84	25.2	34.6	52.8	8.1	6.6	94.7
S2JUL	08/07/2010	92.3	27.1	33.4	52.8	8.1	7.8	118.5
S3JUL	08/07/2010	53.0	28.7	25.6	43.0	8.2	8.5	124.1
SIOCT	19/10/2010	90.3	18.2	33.2	44.2	7.9	7.3	95.0
S2OCT	19/10/2010	79.0	16.2	28.6	37.0	7.8	7.1	86.9
S3OCT	19/10/2010	80.3	17.2	24.7	28.7	7.6	4.9	57.8
S1JAN	18/01/2011	79.3	12.5	25.0	39.2	8.3	8.0	87.5
S2JAN	18/01/2011	79.3	11.4	21.3	33.8	8.2	8.3	87.9
S3JAN	18/01/2011	101.0	11.8	21.8	33.4	9.0	8.3	87.9
S1APR	28/04/2011	92.0	17.7	27.6	37.1	7.9	9.0	111.0
S2APR	28/04/2011	126.0	18.3	24.2	33.2	8.0	10.3	126.9
S3APR	28/04/2011	106.0	18.4	15.0	19.4	7.8	7.2	80.8

Tabella 2 - Values of the water variables at different stations and months in Fogliano and Caprolace lagoons.

Station	Date	Depth (cm)	T (°C)	Salinity (psu)	Station	Date	Depth (cm)	T (°C)	Salinity (psu)
F1FEB	03/02/2011	100	9	36	F6SJUL	14/07/2011	100	30	44
F2FEB	03/02/2011	90	9	36	F7JUL	14/07/2011	80	29	44
F3FEB	03/02/2011	200	9	34	F8JUL	14/07/2011	80	29	44
F4FEB,	03/02/2011	89	9	38	C1FEB	03/02/2011	100	9	39
F5FEB	03/02/2011	70	10	33	C2FEB	03/02/2011	90	9	36
F6FEB	03/02/2011	100	9	38	C3FEB	03/02/2011	250	9	38
F7FEB	03/02/2011	80	10	34	C4FEB	03/02/2011	200	9	38
F8FEB	03/02/2011	80	10	33	C5FEB	03/02/2011	90	10	36
F1MAY	06/05/2011	100	20	31	C6FEB	03/02/2011	80	10	36
F2MAY	06/05/2011	90	21	35	C1MAY	06/05/2011	100	21	42
F3MAY	06/05/2011	200	20	35	C2MAY	06/05/2011	90	21	40
F4MAY	06/05/2011	89	20	31	C3MAY	06/05/2011	250	20	40
F5MAY	06/05/2011	70	18	38	C4MAY	06/05/2011	200	20	40
F6MAY	06/05/2011	100	20	38	C5MAY	06/05/2011	90	21	38
F7MAY	06/05/2011	80	20	31	C6MAY	06/05/2011	80	20	38
F8MAY	06/05/2011	80	20	31	C1JUL	15/07/2011	100	28	44
F1JUL	14/07/2011	100	30	50	C2JUL	15/07/2011	90	28	45
F2JUL	14/07/2011	90	29	44	C3JUL	15/07/2011	250	28	50
F3JUL	14/07/2011	200	30	48	C4JUL	15/07/2011	200	28	48
F4JUL	14/07/2011	89	30	48	C5JUL	15/07/2011	90	28	50
F5JUL	14/07/2011	70	25	44	C6JUL	15/07/2011	80	26	48

and conductivity decreased from July (34.6 psu, 52.8 mS/cm; 33.4 psu, 52.9 mS/cm, respectively) to January (25.0 psu, 39.2 mS/cm; 21.3 psu, 33.8 mS/cm, respectively) and increased in April (27.6 psu, 37.1 mS/cm; 24.2 psu, 33.2 mS/cm, respectively), while in station S3 salinity decreased from July (25.6 psu, 43.0 mS/cm) to April (15.0 psu, 19.4 mS/cm). In Fogliano and Caprolace lagoons salinity showed a wide range, with a variation between polyhaline and hyperhaline values (31-50 psu). Dissolved O_2, in Santa Gilla lagoon, varied between the lowest value measured in October in Station S3 (4.9 mg l^{-1}; 57.8 % Sat), and the highest value in April in Station S2 (10.3 mg l^{-1}; 126.9 % Sat), while the values of pH ranged from 7.6 to 9.0.

A total of 180 individuals were collected at Santa Gilla; all the specimens were found in the two stations nearest to the sea, 159 individuals in October in station S1, and 21 individuals in station S2, mostly in October, when salinity ranged from 29 to 33 psu. No specimens were found in station S3, near to the freshwater inflows, where salinity ranged from 13 to 26 psu.

Multiple regression analysis showed that the abundance of individuals in the samples was not correlated with abiotic variables ($P>0.05$).

In Caprolace and Fogliano lagoons only 6 individuals (three in each lagoon) of *C. scaura* were collected, this being in May on a sandy-muddy bottom with abundant vegetation of rhizophite species (*Zostera noltii* at Fogliano and *Cymodocea nodos*a at Caprolace). Samples from Santa Gilla at station S1 in October were mainly characterized by juveniles (67.9%) and immature females (18.2%). At station S2 both in October and

Figure 2. Frequency distribution of the 5 categories in the different stations and seasons (S1OCT = Santa Gilla station S1, October; S2OCT = Santa Gilla station S2, October; S2JUL = Santa Gilla station S2, July; F5MAY = Fogliano station F5, May; C6MAY = Caprolace station C6, May).

in July the population proved to be almost equally composed of the different categories (Fig. 2). The total number of females sampled was much higher than that of males (sex ratio=0.88).

Specimens from Fogliano and Caprolace were found only in the stations close to the sea and were mostly composed of females. Three immature females were found in station C6 while two breeding females and one juvenile were found in station F5.

Overall, the length distribution of Santa Gilla specimens showed a range in size between 1.4 and 7.3 mm (mean±SD=3.5±1.2), males (LT = 5.1-7.3 mm; mean±SD = 6.1±0.85) proving to be longer than females (mature females LT = 4-5.3 mm, mean±SD = 4.7±0.4; immature females LT= 2.2-6.2 mm, mean±SD = 4.1±0.96; breeding females LT=4.9-6.2 mm, mean±SD = 5.7±0.5) and juveniles (LT = 1.4-4.2 mm; mean±SD = 2.8±0.7) (Fig. 3). Kolmogorov-Smirnov test, showed significant differences ($P<0.05$) between samples from station S1 and S2 during October. In Caprolace the total length of the immature females ranged from 3.4 mm to 4.9 mm (mean±SD = 4.4±0.8). In Fogliano the breeding females were 6.1-9.3 mm (mean±SD = 7.7±2.3) and the juvenile 1.7 mm in length. The egg count was possible only in two specimens due to their leakage from the brood pouch in the rest of individuals. The number of eggs found was respectively 70 and 30. The dimensions of the eggs in the first brood pouch showed a range in size from about 122 to 263 µm (mean±SD = 191±35). The eggs found in the second brood pouch varied in size from about 225 to 325 µm (mean±SD = 279±42). The value of the partial fecundity index was 9.5 and the age of reaching maturity index was 0.9.

Discussion

Colonization of the area nearest to the sea both at Santa Gilla and at Fogliano and Caprolace highlighted *Caprella scaura'* affinity for coastal marine waters. Indeed, all the specimens were found in the stations

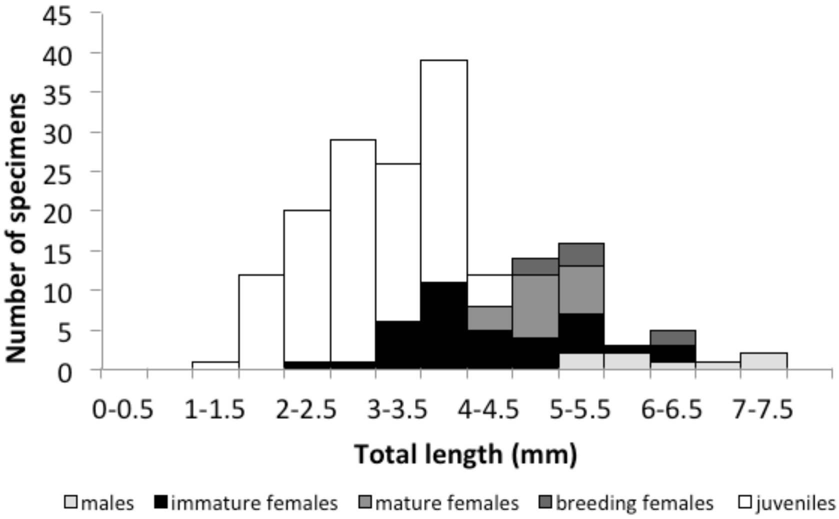

Figure 3. Size-frequency distribution of the whole population (N=180) of *Caprella scaura* in the Santa Gilla lagoon.

nearest to the sea and none in the inner areas of the lagoons.

The species' massive abundance observed in the Santa Gilla lagoon only in October and the comparatively scarce records in other months demonstrates that the population status has not yet stabilized, even though the presence of breeding females and the high number of juveniles indicate suitable conditions for the species' eventual establishment in future. As observed also by Prato *et al.* (2013) for the Mar Piccolo of Taranto, the abundance of individuals in the samples was not correlated with environmental parameters.

The albeit scarce records suggest that the introduction of the species in Fogliano and Caprolace lagoons could have been a recent event, given that previous monitoring studies had found other species of caprellid, such as *Caprella aequilibra* and *Phtisica marina* (Gravina, 1986; Nicoletti *et al.*, 2006).

Because of lacking a planktonic larval stage, the colonization of lagoon environments is due to adult dispersal; in fact, adults can be passively transported by rafting connected with some human activities, such as vessel traffics and aquaculture. In the Santa Gilla lagoon the passive dispersal of *C. scaura* is explained by its closeness to two ports and the activity of mussel farms, together with the reintroduction of the oyster *Ostrea edulis* in 2003 and of various allochthonous species, the clam *Ruditapes philippinarum* in 1996, the shrimp *Marsupenaeus japonicus* and the oyster *Crassostrea gigas* in 2004. On the contrary, in Fogliano and Caprolace lagoons such hypothesis of dispersal mechanism has to be rejected because these lagoons are included in a protected area where such human activities are prevented.

The immature females from Caprolace proved to be in the length range of the specimens from Santa Gilla, while breeding females from Fogliano reached the largest length of 9.3 mm. The specimens from Tyrrhenian lagoons examined were smaller than those of other Mediterranean areas, as reported by Martinez and Adarraga (2008) for Gerona and by Krapp *et al.* (2006) for Greece and Sicily. These differences in size could be related to environmental conditions, such as water temperature, food and substrate availability or competition with other species, as suggested by Guerra-Garcia *et al.* (2011) for Cadiz. They also appear smaller than the ones reported by Prato *et al*. (2013) for the Mar Piccolo of Taranto.

Furthermore, the sex ratio appears different: the sex ratio of the samples taken from the Mar Piccolo of Taranto is close to 1:1, while the sex-ratio values of the samples taken from Santa Gilla, Fogliano and Caprolace lagoons are female-biased. This could be related to the criteria used to distinguish the genders: Prato *et al.* (2013) used the development of oostegites to distinguish immature females from males, using a modification of Takeuchi and Hirano (1991), whereas in this study all the characteristics above described were used, the absence of oostegites being insufficient to discriminate between the two genders (Takeuchi and Hirano, 1991). Moreover, a female-biased sex ratio is a common feature for amphipods (Prato *et al.*, 2013) and could prove an advantage in the invasive species since a great number of females increases the population's reproductive capacity (Devin *et al.*, 2004).

C. scaura, moreover, is a highly competitive species which displays inter-intraspecific aggression towards other members of the community (Lim and Alexander, 1986). The endemic caprellid *Pseudolirius kroyerii*, recorded in Santa Gilla, could be a potential competitor of *C. scaura*, while in Caprolace, several specimens of other caprellid species represent possible competitors, they having colonized both the areas under marine influence and the confined ones.

In general, some biological traits seem to facilitate the colonization of new areas and competition with native species, as a large brood size, high fecundity and early maturation. The specimens coming from Santa Gilla lagoon showed a low fecundity, although the number of eggs was greater than those from Mar Piccolo of Taranto, analyzed by Prato *et al*. (2013), and maturity was reached at an earlier size.

C. scaura, specifically, has a peculiar life strategy with some aspects typical of the "*r*" strategy, such as a short life span of 6-8 months (Prato *et al*., 2012), fast reproductive cycle, and some characteristics of the "*K*" strategy, e.g. a low number of eggs, maternal care and close association between mother and young, that may persist for up to one week after emergence (Lim and Alexander, 1986). The Santa Gilla population were also closer to an r-strategy than were the population from the Mar Piccolo of Taranto analyzed by Prato *et al*. (2013), indeed the number of eggs was greater and maturity was reached at an earlier size.

Conclusions

The first record of *Caprella scaura* in the lagoons of Sardinia and Latium suggests that it is a potential invasive alien species, even if the impact of an introduced species can be appreciated only by intensive and long-lasting studies after mass occurrence in a new habitat (Occhipinti Ambrogi, 2001), a species being defined invasive only when it reaches high densities and spreads further. Therefore, to evaluate the real invasive success of this species the monitoring should be extended to other areas of the lagoons and increased in number and frequency.

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